LETTERS TO THE EDITOR

ASTRONOMY

Helium in the Galactic Disk *B* Stars

Greenstein and Münch[1], and Sargent and Searle[2], have recently shown that the atmospheric helium abundance in the halo and globular cluster *B* stars is low compared with that for normal *B* stars in the Galaxy. Greenstein, Truran and Cameron[3] have suggested that the low abundance may be the result of gravitational diffusion of helium from the atmosphere to a lower layer within the star. They consider that normally mixing currents set up by stellar rotation would counteract such diffusion. In contrast to galactic disk *B* stars, most of the halo stars appear to be slow rotators. This result is apparently confirmed by Sargent and Strittmatter[4], who have discussed the weak helium line stars in Orion and conclude that they are intrinsically slow rotators, and that the anomaly is an atmospheric one.

In this communication we would like to report related results on 425 field *B* stars which suggest that the apparent helium abundance depends on the rotational velocity. The observational data are taken from Walker and Hodge[5].

There is a significant positive correlation for spectral types *B*2 to *B*5 between the equivalent widths of the He I lines at wavelengths of 4388 and 4471 Å, and the values of the projected rotational velocity $v \sin i$, based on the half widths of the two He I lines. The correlation between the equivalent widths of Hγ, a measure of surface gravity, and $v \sin i$ is always much smaller than that between the He I lines and $v \sin i$ and not always of the same sign. The relevant correlation coefficients between the logs of the observed quantities are given in Table 1. W refers to equivalent width and the subscripts identify the line. For the He I lines we use the correlation between $\log W_{4471}$ and $\log (v \sin i)_{4388}$ to eliminate any effects of errors of measurement in W and $v \sin i$ for the same line. The number of stars in each group is given by n. An example of the correlation for *B*4 stars is shown in Fig. 1.

After examination of the reduction procedure, we have concluded that systematic errors in estimating the level of the continuum or the line profile are not responsible for the correlation between $\log W_{4471}$ and $\log (v \sin i)_{4388}$. There is clearly a considerable scatter, since none of the correlation coefficients is very high. The distribution of points at all spectral types is, in fact, triangular (see Fig. 1), an effect which can be understood if the helium line intensities are sensitive to rotational velocity v but insensitive to $\sin i$. According to Greenstein and Münch[1], the effects of changes in temperature and pressure over the surface caused by the rotation are expected to be small, and this is confirmed by our observation that the variation of the equivalent widths from type to type is less than the scatter within each type. We could improve the correlations considerably in the range 09 to *B*2 and at *B*5 by rejecting five very deviant points, but we prefer not to do this, since there is no other evidence that these stars are peculiar. These are, however, the only stars out of 425 which show low W_{4471} and high $v \sin i$.

Table 1. CORRELATION COEFFICIENTS FOR SPECTRAL TYPES *B*0 TO *B*5

Spectral type	(W_{4471}, $v \sin i$) r^*	($W_{H\gamma}$, $v \sin i$) r^*	n
09, *B*0	0·05	0·12	46
*B*1	0·01	0·00	69
*B*2	0·26	−0·04	66
*B*3	0·32	−0·15	130
*B*3*e*	0·63	−0·36	23
*B*4	0·60	0·24	48
*B*5	0·29	0·02	66

r^*, Correlation coefficient between the logs of the quantities in parentheses.

The *B*3*e* stars were analysed as a separate group since the emission line stars have been thought to be rapidly rotating, and the observed variation of the equivalent widths of the He I lines with $v \sin i$ would then reflect largely a variation with $\sin i$ not v.

The frequency of *B*3*e* stars with low $v \sin i$, however, appears to be incompatible with a uniformly high v and a random distribution of i. Some of our *B*3*e* stars must therefore be intrinsically slow rotators. A similar conclusion is reached by Schild[6] in a study of the *Be* stars in *h* and χ Persei. The *Be* stars, therefore, give us no information about $\sin i$ effects. The behaviour of the helium lines in *B*3*e* stars is, in fact, observed to parallel that of the normal *B*3 stars. Sharp line *B*3 and *B*3*e* stars have similar He I lines (Sargent and Searle[7]), but this cannot be used as evidence for the absence of $\sin i$ effects. Other arguments such as those made previously must be used. Visual inspection of the original plates shows that other He I lines behave in the same way as those at 4471 and 4388 Å.

These results are qualitatively compatible with any mechanism for removing helium from the atmospheres of slowly rotating stars, such as that of Greenstein, Truran and Cameron, and consistent with the arguments of Sargent and Strittmatter that the abundance anomalies cannot extend far into the interior of the stars. Caution must therefore be exercised in comparing the helium content of the atmospheres of certain stars with the implications of some cosmologies concerning primordial helium abundance. A more detailed account of this research will appear elsewhere.

We thank Dr. N. Woolf for helpful discussions, and the U.S. Office of Naval Research for partial support.

T. J. DEEMING

Department of Astronomy,
University of Texas,
Austin, Texas.

G. A. H. WALKER

Dominion Astrophysical Observatory,
Victoria, B.C., Canada.

Received December 30, 1966.

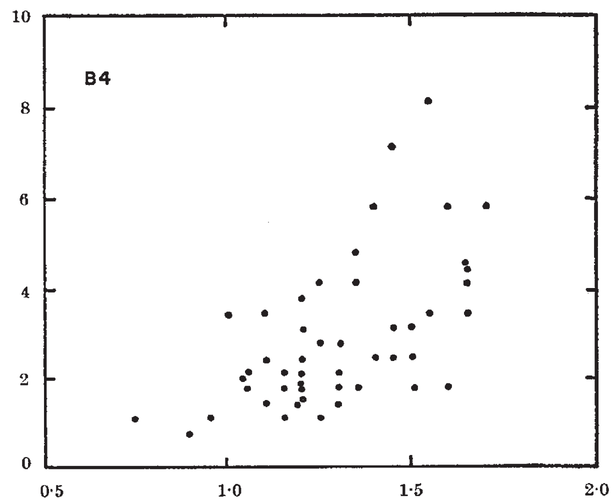

Fig. 1. The relation between the equivalent width W of the He I line at 4471 Å and the half-width H of the He I line at 4388 Å for *B*4 stars, showing the effect of rotational velocity, which determines H, on the strength of the He I lines.

[1] Greenstein, J. L., and Münch, G., *Astrophys. J.*, **146**, 618 (1966).
[2] Sargent, W. L. W., and Searle, L., *Astrophys. J.*, **145**, 652 (1966).
[3] Greenstein, G. S., Truran, J. W., and Cameron, A. G. W., *Nature* (in the press).
[4] Sargent, W. L. W., and Strittmatter, P. A., *Astrophys. J.*, **145**, 938 (1966).
[5] Walker, G. A. H., and Hodge, S. M., *Publ. Dom. Astr. Obs.*, **12**, 401 (1966).
[6] Schild, R. E., *Astrophys. J.*, **146**, 142 (1966).
[7] Sargent, W. L. W., and Searle, L., *Observatory*, **86**, 27 (1966).